Dairy Processing Technology Centre

Stakeholder Landscape Analysis

Challenges and Opportunities for the Irish Dairy Sector in the Circular Bioeconomy

Author: Dr Abigail Pattenden, DPTC Funding Officer

Contributors: Dr Anne Marie Henihan (DPTC Centre Director), Paudie Fitzgibbon (DPTC Business Development Officer), Dr Niamh Burke (DPTC Technical Lead), Orla Kelly (DPTC Marketing and Operations Officer), Dr Anna Piterina (DPTC Programme Officer)

October 2024

Stakeholder Analysis Report – Circular Dairy Bioeconomy

What this report is about:

The Dairy Processing Technology Centre (DPTC) conducted a comprehensive stakeholder analysis to identify opportunities for the dairy sector to decarbonise and contribute to sustainable food systems. This analysis emphasises the circular bioeconomy as a key pathway to achieving these goals throughout the value chain. This report presents a summary of the findings, providing insights into how the dairy industry can innovate and adapt to meet sustainability challenges.

Who we are:

The Dairy Processing Technology Centre (DPTC) is a leading collaborative Research and Technology Centre dedicated to driving innovation in the dairy processing industry. It addresses common sectoral challenges and focuses on creating value, enhancing competitiveness, and promoting sustainability within the industry. DPTC leverages expertise from leading academics and industry partners to deliver impactful research and solutions that meet the evolving needs of the dairy sector.

DPTC is made up of seven Irish dairy processors: Kerry, Dairygold, Lakeland Dairies, Tipperary Co-Op, Arrabawn Co-Op, Carbery and Tirlán, and six Research Performing Organisations: University of Limerick, University College Dublin, Trinity College Dublin, University College Cork, University of Galway and Teagasc. DPTC is funded by Enterprise Ireland and the industry partners through the Technology Centres Programme.

Acknowledgements:

The authors wish to thank Dr John Garvey and Prof. Fergal O'Brien from the Kemmy Business School and the BIOFIN-EU project for their invaluable assistance in preparing the surveys. Appreciation is also extended to all survey respondents, as well as the moderators and speakers at the circular dairy workshop.

Disclaimer: This document is for informational purposes, based on data from surveys and a stakeholder workshop in September 2024. The views expressed are the authors' and do not reflect the official policy of any affiliated organisations

Contents

Workshop and Survey Respondents

Arrabawn Co-op
Bank of Ireland
Bioeconomy Foundation
BIOFIN
BiOrbic
Bord Bia
Carbery
Cill Ulta
Circular Bioeconomy Cluster Southwest
Dairy Industry Ireland, IBEC
Dairy Processing Technology Centre
Dairygold
Dept. of Environment, Climate and Communications
Dept. of Agriculture, Food and the Marine
Enterprise Ireland
European Biogas Association
Food and Bio Cluster, Denmark
Gas Networks Ireland
Irish Co-operative Organisation Society
Inform Bio
International Synergies
Kemmy Business School
Kerry
Lakeland Dairies
Lisavaird Co-op
Lisheen
Munster Technological University
Ornua
Queen's University Belfast
Renewable Gas Forum Ireland
SSE
Teagasc
Tipperary County Council
Tirlán
Trinity College Dublin
University College Dublin
University of Galway
University of Limerick

Executive Summary

The Irish dairy sector, a key economic driver, faces both challenges and opportunities in its efforts to decarbonise and meet sustainability targets. Utilising the circular bioeconomy can help achieve these goals, but it also introduces specific risks and challenges that need to be addressed. This Stakeholder Landscape Analysis, informed by surveys and a stakeholder workshop carried out by DPTC and Kemmy Business School in September 2024, outlines key challenges and offers recommendations to enhance sustainability and economic resilience. The analysis aims to identify specific trends, concerns, and opportunities within the sector, providing a foundation for future actions.

Key Stakeholder Recommendations

High Investment Costs: Significant up-front costs for infrastructure and technology are a major barrier. Financial incentives such as grants, subsidies, tax credits, and low-interest loans, along with public-private partnerships, are essential to mitigate these costs.

Market Development: Developing robust markets for biobased products is crucial. Enhancing consumer perception through education and independent validation can help classify outputs as 'products' rather than 'waste'.

Stable Supply Chain: Ensuring a consistent supply of feedstocks is vital. Diversifying feedstocks and involving local communities can help manage seasonal variations and contaminants.

Regulatory Support: Clear and consistent regulatory frameworks, including flexible regulations for early adopters, are necessary to support the transition.

Technological Innovation: Ongoing research, pilot projects, and demonstration sites are critical for advancing circular technologies. Centralised bio-refining can enhance efficiency and resource use.

Collaboration and Knowledge Sharing: Cross-sectoral collaboration and knowledge sharing are key to success. Adapting international best practices to the Irish context can provide valuable insights.

Background

The dairy industry stands at the forefront of sustainable food systems, guided by the principles outlined in Food Vision 2030. This vision aims to elevate the sustainability of the agri-food sector by embracing circular bioeconomy practices, with key strategies including reducing food waste and food loss, and improving resource use efficiency, ensuring that every step from farm to fork contributes to a more sustainable future. By focusing on minimising the environmental impacts of dairy production and processing,

the dairy sector strives for long-term sustainability, adhering to stringent environmental regulations and implementing innovative solutions to protect Ireland's natural resources.

By embracing circular bioeconomy principles and leveraging innovative practices and cascading biorefinery opportunities, the dairy value chain can significantly enhance sustainability, boost decarbonisation efforts, and promote economic viability. At the factory level, converting dairy co-products like whey into valuable products such as bio-based chemicals, biodegradable plastics, and bioenergy helps reduce waste and lower the carbon footprint. On farms, biorefinery processes treat manure and organic waste to produce biogas for renewable energy and nutrient-rich digestate for natural fertilisers, promoting a circular nutrient economy. Beyond the farm and factory, integrating biorefinery processes with other agricultural sectors creates synergies, such as using crop residues for bioenergy, and developing integrated biorefinery hubs that serve multiple industries. Implementing these processes enhances sustainability, economic resilience, and contributes to decarbonisation across the dairy value chain.

Stakeholder Views and Recommendations

Stakeholders identified several major challenges for the dairy sector in transitioning to a circular bioeconomy. These challenges include high up-front investment costs for infrastructure, technology, and production facilities, as well as inconsistent and complex regulatory frameworks. To address these issues, stakeholders emphasised the need for financial incentives such as capital grants, subsidies, tax credits, certificates of sustainability to offset emissions, and low-interest loans. Public-private partnerships and direct financial support are also vital to overcome high investment costs.

Another critical challenge is developing robust markets for biobased products and improving consumer perception. Stakeholders recommended promoting cooperative models to manage supply risks and support market engagement, distributing risks and benefits more evenly among stakeholders. Enhancing consumer perception by classifying outputs as 'products' rather than 'waste' through independent validation and consumer education initiatives is essential, as is addressing consumer concerns regarding the quality and price of bio-based products through quality control measures.

Ensuring a consistent and reliable supply of feedstocks and raw materials is another significant challenge due to seasonal variations and the presence of contaminants. Stakeholders identified the diversification of feedstocks and the involvement of local communities and cooperatives as crucial for ensuring supply stability in the circular bioeconomy. Recommendations included using industrial by-products and resource matching databases to reduce reliance on traditional agricultural inputs and build resilience. Supportive government policies and regulations are needed to facilitate the use of diverse feedstocks and address regulatory hurdles related to material classification.

The complexity and novelty of circular technologies also pose significant risks. Stakeholders highlighted opportunities such as nutrient recycling, biomethane production, and biorefining that can be harnessed to transform dairy co-products into valuable resources. Centralised bio-refining can enhance efficiency and resource use. They emphasised the importance of ongoing research and development, optimising technologies such as high-rate reactors and feedstock enhancement and conducting pilot projects and demonstration sites to drive innovation and practical implementation.

Inconsistent and complex regulatory frameworks were identified as a major challenge. Establishing clear regulatory frameworks, including flexible regulations for early adopters, is vital. Cross-sectoral collaboration and knowledge sharing through formal frameworks and educational programmes should be encouraged.

Additionally, stakeholders suggested adapting successful models from other countries to the Irish context for effective circular bioeconomy practices. Supporting pre-competitive positions across the dairy sector will be important, along with implementing carbon pricing mechanisms and benchmarking against the price of carbon. For example, companies under the EU Emissions Trading System (ETS) must have robust emissions accounting and accredited certificates for compliance. Though the ETS doesn't fully cover the dairy value chain, there are proposals to include agricultural emissions. These proposals aim to incentivise carbon recovery and decarbonisation by potentially including dairy processors or farmers in the scheme[1].

Next steps

Ireland's circular bioeconomy sector is thriving, with numerous initiatives and forums supporting its growth. Recent progress includes the launch of the Biomethane Strategy and investments in pilot plants and demonstrator facilities under the Just Transition initiative.

However, the Stakeholder Analysis highlights the need to better understand government-led initiatives, technological opportunities, and market conditions to support dairy sector decarbonisation. Findings will be shared with key representatives in the Department for Agriculture, Food and the Marine (DAFM) and the Irish Bioeconomy Forum Stakeholder group. DPTC will collaborate with Kemmy Business School to further explore the transition from a linear to a circular bioeconomy.

A detailed analysis of collected data will identify trends, concerns, and opportunities, helping to develop actionable plans for economic resilience. Continuous stakeholder engagement will ensure ongoing collaboration and the success of these initiatives.

[1] EU ETS Scheme

Introduction

The Irish dairy sector is a cornerstone of the national economy, contributing significantly to rural development and employment. In 2022, the sector generated €17.6 billion in economic value, supporting nearly 54,000 full-time equivalent jobs[2]. Ireland's dairy industry is renowned for its high-quality, grass-fed products, with approximately 90% of dairy output exported to over 120 countries[3]. This global reach underscores the sector's importance not only to the Irish economy but also to its international trade relations.

Transitioning to a circular bioeconomy presents a significant opportunity for the Irish dairy sector to enhance sustainability and commercial competitiveness. In Ireland, most of the carbon footprint in dairy sector comes from the farm, with only a small proportion from the factory. This highlights the importance of an integrated approach to decarbonising the entire dairy value chain.

The circular bioeconomy offers substantial economic, environmental, and social benefits. It plays a crucial role in mitigating climate change by lowering greenhouse gas emissions and encouraging sustainable practices [4]. Additionally, it emphasises sustainable food production methods that minimise waste and utilise biobased materials, supporting the development of a modern, sustainable society. By addressing emissions at every stage of the dairy value chain - from farming practices to processing and distribution - significant carbon savings can be achieved. It is also crucial to communicate these efforts transparently to consumers, helping them make informed choices and supporting the overall goal of reducing the dairy industry's environmental impact.

Government policy documents such as the Climate Action Plan 2024[5], the Food Vision 2030 Strategy[6], the Bioeconomy Action Plan[7], and the Circular Economy Strategy 2022-2023[8], further support the development of the circular bioeconomy. These policies provide a framework for integrating circular practices into the dairy sector, promoting innovation, and ensuring long-term sustainability. The National Biomethane Strategy[9] is a critical first step in this transition, emphasising the importance of anaerobic digestion (AD) embracing circular business models, and providing significant opportunities for the dairy industry to enhance sustainability and economic resilience.

[2] Ibec
[3] Teagasc
[4] EPA Circular Bioeconomy Outlook Study 2030-2050
[5] Climate Action Plan 2024
[6] Food Vision 2030 Strategy
[7] Bioeconomy Action Plan 2023 – 2025
[8] Whole of Government Circular Economy Strategy 2022-2023
[9] Ireland's National Biomethane Strategy

The Corporate Sustainability Reporting Directive (CSRD) is another key regulatory framework supporting this transition [10]. By mandating comprehensive sustainability reporting, CSRD ensures transparency and accountability, driving the adoption of sustainable practices across the dairy sector.

The Irish dairy sector is actively working towards transitioning to a low-carbon economy, despite facing significant challenges in a volatile market where customers increasingly demand evidence of reduced carbon footprints. Currently, agriculture contributes approximately 38% of national greenhouse gas emissions, primarily from methane and nitrous oxide. The dairy sector accounts for 40% of these agricultural emissions, which translates to approximately 15% of the total national GHG emissions[11]. Additionally, high levels of nitrogen run-off from dairy farms impact water quality, particularly in the south and south-east of Ireland, where dairy farming is more concentrated. To meet the agricultural and industry greenhouse gas emissions targets, of 25% and 35% reduction respectively by 2030, comprehensive decarbonisation efforts are required across the entire dairy value chain, from farm to fork, including dairy factories. While progress is ongoing, achieving these targets will require coordinated and sustained efforts from all stakeholders across the sector.

Adopting circular practices such as nutrient recycling and recovery, anaerobic digestion (AD), and biorefining can transform dairy co-products into valuable bio-based resources, creating new value streams, enhancing both economic viability and environmental sustainability. For instance, a notable example of in-factory side stream valorisation in dairy ingredient manufacturing is the bioconversion of whey permeate (WP) and delactosed permeate (DLP) into bio-based lactic acid (LA). However, biorefining and valorisation technologies remain underexploited and represent crucial avenues for further value creation within the sector. AD, meanwhile, can convert manure, dairy processing sludge and other organic wastes into biogas, providing a renewable energy source that can reduce energy costs and generate additional revenue. AD for dairy processing sludge is particularly viable, supporting dairy processors in decarbonising their factories. By displacing fossil fuel dependency through the generation of thermal energy, processors can contribute significantly to sustainability goals.

Moreover, a circular bioeconomy can stimulate innovation, create jobs, and improve resource security by reducing dependency on external inputs, such as mineral fertilisers, and enhancing soil health[12]. This makes it a vital strategy for the future resilience of the Irish dairy industry.

[10] Corporate Sustainability Reporting Regulations
[11] GHG Emissions
[12] Environmental Impact of Dairy Farming

Stakeholder Analysis

The Dairy Processing Technology Centre (DPTC) is an industry-led research hub, partially funded by dairy processors who oversee dairy product manufacturing. DPTC tackles factory-based challenges such as process optimisation, water and energy reduction, nutrient recovery, side stream valorisation, on-site AD and sludge valorisation. Through its research, DPTC has developed numerous solutions such as feedstock enhancement of dairy processing sludge to increase the biomethane potential. However, there is a lack of clarity regarding the opportunity to monetise these opportunities within the biomethane and circular bioeconomy. The goal is to support the sector decarbonise and ensure economic resilience. To identify market enablers, DPTC convened key stakeholders from government, anaerobic digestion, research, farming, technology and solution providers, and dairy processing.

The objectives of this Stakeholder Landscape Analysis are to identify key areas of concern and build consensus to help transition the Irish dairy sector to a circular bioeconomy.

It aims to highlight key obstacles, provide strategic recommendations, promote stakeholder collaboration, enhance sustainability and economic resilience, outline further research needs, and engage the community and consumers. By achieving these objectives, the analysis seeks to offer clear recommendations for a sustainable and resilient circular bioeconomy in the Irish dairy sector.

Methodology

To develop a comprehensive stakeholder analysis on the circular dairy bioeconomy, a multi-phase approach involving surveys and a virtual workshop was employed.

Phase 1: Initial Survey An initial survey captured perspectives from stakeholders across the dairy sector. It included questions on nutrient circularity, conversion technologies, anaerobic digestion, feedstock enhancement, biorefining, and carbon capture and reuse. Respondents included academics, dairy processors, financial services professionals, and other industry stakeholders.

Phase 2: Follow-up Survey Based on the initial survey results, three key areas were identified: finance risk factors, market design, and policy and regulation. A second survey, using the Delphi technique, focused on these areas to achieve a consensus among experts. The follow-up survey refined the understanding of critical issues and potential solutions.

Phase 3: Virtual Workshop All original stakeholders were invited to a virtual workshop attended by 54 participants. The workshop began with expert talks, followed by breakout sessions on finance factors, market design, and policy and regulation. Detailed notes were recorded to capture discussions and insights.

Structure of the Stakeholder Analysis

The structure of the stakeholder analysis is organised around the key areas of importance identified through the surveys and workshop discussions.

Challenges:
Each section begins with a description of the challenges associated with that area. This provides context and highlights the issues that need to be addressed to transition to a circular bioeconomy.

Recommendations:
The recommendations section outlines immediate actions or strategies that stakeholders can implement to address the identified challenges. These are more concrete and actionable steps that can be taken in the short to medium term.

Further Work Needed:

The further work needed section highlights areas that require additional research, development, or long-term planning. This section focuses on the broader, ongoing efforts necessary to support the transition to a circular bioeconomy over a longer period.

Market Design and Supply

Challenges: **Market development, customer perception, supply chain stability**

Key Market Risk Factors Preventing the Success of a Circular Business Model

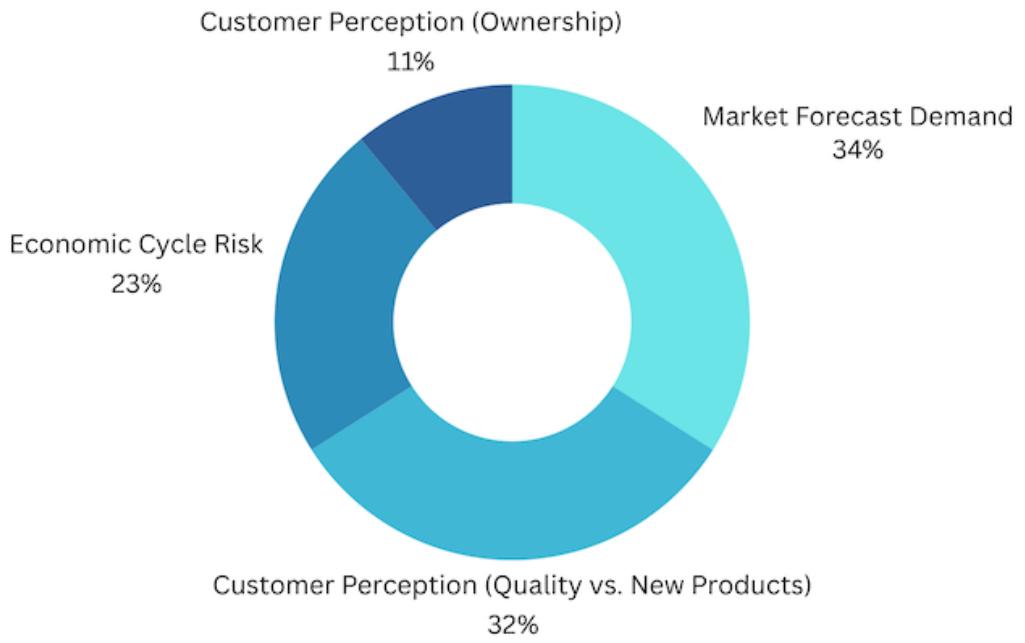

Figure 1: Percentage stakeholder responses to the question **"What is the key market risk factor preventing the success of a circular business model?"**

Market forecast demand (uncertainty of market size, 34%) and **Customer perception** (Quality vs. new products – resistance of end-users towards CE products, 32%) were deemed the most important risk factors. **Economic cycle risk** (in the business environment/market due to adverse economic cycle and/or uncertain financial stability, resulting in low demand for products at the global level, 23%). **Customer Perception** (Ownership – resistance of end-users towards CE products due to preference of customers for ownership rather than access to service resulting in low public acceptance of products, 11%).

The Irish dairy sector faces several challenges in market design and supply as it transitions to a circular bioeconomy. One significant challenge is market development, which requires creating a robust market for biobased products and ensuring a level playing field for both small and large businesses. Circular practices can enhance the economic viability of dairy farming and processing by optimising resource use and reducing waste. For example, integrating anaerobic digestion (AD) with biorefining processes can add value by extracting high-value materials from dairy co-products, creating new revenue streams, and improving market stability.

Market Design

The results of the stakeholder surveys and workshops revealed significant concerns regarding market forecast demand for circular business models in the dairy sector. The primary concern is the uncertainty about the market size for biobased products, which makes it challenging to predict demand and plan investments effectively.

Additionally, stakeholders highlighted the need for consumer awareness and acceptance of circular bioeconomy products. There is a perception that these products may be of inferior quality compared to traditional products, which can hinder market penetration and growth. Overcoming this perception is crucial for developing a robust market for biobased products. Moreover, customers are increasingly demanding clear evidence that the products they purchase come from suppliers actively working to decarbonise their operations.

Economic cycle risks also play a role, as adverse economic conditions and financial instability can lead to reduced demand for circular bioeconomy products. This volatility makes it difficult for businesses to commit to long-term investments in circular practices.

Recommendations

Market Development: Stakeholders stressed the importance of creating robust markets for bio-based products. The need for supportive government policies and regulations to facilitate the use of diverse feedstocks and address regulatory hurdles related to material classification was highlighted. This includes harmonising end-of-waste criteria at the national level and providing clear guidelines for the use of bio-based products. Developing robust markets for bio-based products, such as bio-methane and bio-fertilisers, was seen as crucial. This involves creating demand through policies such as renewable heat obligations and ensuring that bio-based products are competitive with their fossil-based counterparts.

Improve Consumer Perception: Enhance consumer perception by classifying outputs as ‘products’ rather than ‘waste’ through independent validation and consumer education initiatives. Involving the community can further improve acceptance and trust. Additionally, addressing consumer concerns regarding the quality and price of bio-based products through quality control measures is essential to build trust and acceptance.

Economic Incentives: Provide financial incentives such as grants, subsidies, tax credits, and low-interest loans to reduce the financial burden on businesses adopting circular practices. These incentives can help mitigate the risks associated with market uncertainty and encourage investment in circular business models.

Pilot Projects and Demonstration Sites: Invest in pilot projects and demonstration sites to test and refine circular practices. These initiatives can help verify the market potential of new technologies and build confidence among investors and consumers.

Supply Chain Risks

Supply chain stability is also a major concern amongst stakeholders. Ensuring a consistent and reliable supply of feedstocks and raw materials is challenging due to seasonal variations. Strategic management of standards and comprehensive databases[13] for feedstocks are necessary to mitigate these risks and ensure a steady supply chain.

These challenges highlight the need for coordinated efforts to develop markets, improve consumer perceptions, and stabilise supply chains to support the transition to a circular bioeconomy.

Key Supply Risk Factors Preventing the Success of a Circular Business Model

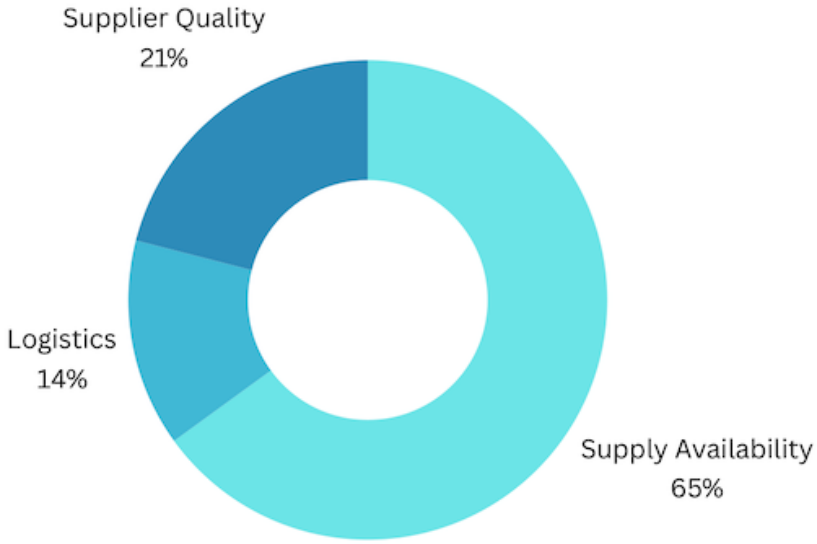

Figure 2: Survey responses to the question **"What is the key supply risk factor preventing the success of a Circular Business Model?"**.

65% of respondents indicated that **supply availability** was the biggest concern – limited and/or not timely availability of recycled materials to support demand of CE final products. **Supplier quality** (quality criteria for the input materials not being achieved) was indicated as the next risk factor (21%). **Logistics risks** associated with changes in the supply network and transportation determining an increase in logistics costs were also noted (14%).

"Availability and quality will be key risks to be managed. We have seasonal Agri systems in Ireland and if homogenous products are required year-round this will be a challenge. However, the dairy sector is already adept at managing this so should be able to plan for this. Where inputs are coming from multiple sources, verifying the quality of the raw materials will be a constant challenge" - ***Stakeholder view***

[13] E.g. InformBio

Recommendations

Ensure Supply Stability: Stakeholders identified the diversification of feedstocks and the involvement of local communities and cooperatives as crucial for ensuring supply stability in the circular bioeconomy. Recommendations included using industrial by-products and resource matching databases, such as the Invest Northern Ireland Resource Matching[14] service, to reduce reliance on traditional agricultural inputs and build resilience. Additionally, supportive government policies and regulations are needed to facilitate the use of diverse feedstocks and address regulatory hurdles related to material classification.

For non-farm-based aspects, stakeholders pointed to the potential use of industrial sludges and by-products from other sectors to enhance supply stability. Developing data capturing systems to manage feedstock availability and characteristics effectively was also recommended.

Promote Cooperative Models: It was noted that cooperative-led initiatives are essential, ensuring that the benefits of biomethane production and carbon credits reach both the sector and the farmers. It is critical that these initiatives support and benefit indigenous sectors.

Cooperative models also manage supply risks and support market engagement, distributing risks and benefits more evenly among stakeholders. This approach fosters a more resilient supply chain by aligning incentives and ensuring long-term commitment.

[14] Resource matching service | Invest Northern Ireland (investni.com)

Policy and Regulatory Support

Challenges: **Regulatory barriers, policy coherence.**

Key Policy and Regulatory Risk Factors Preventing the Success of a Circular Business Model

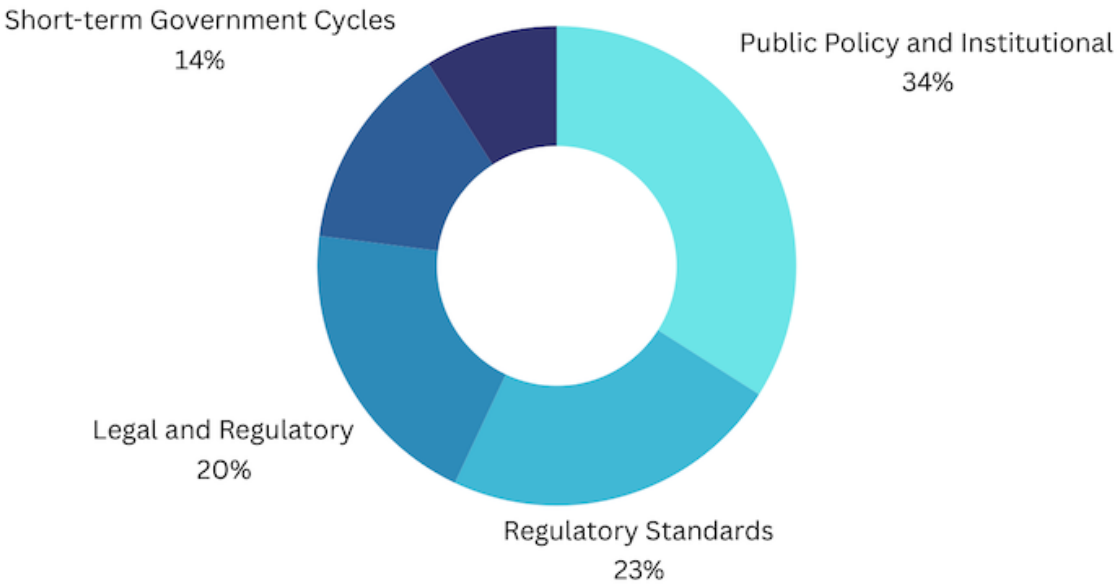

Figure 3: Percentage stakeholder responses to the survey question "**What is the key policy and regulatory risk factor that is preventing the success of a Circular Business Model?"**

Public policy and institutional risks were ranked highest, as adverse changes in policy support schemes or regulations, including economic incentives to shift from a linear to a circular bioeconomy, and/or uncertainty regarding changes in government policies. **Regulatory standards** (lack of standards for circular bioeconomy products, potentially affecting compatibility, quality and sustainable branding) was also noted as a significant risk. **Legal and regulatory risk factors** (commitment of regulatory and legal circumstances, including the ineffectiveness of existing laws and/or their insufficient implementation 20%). **Short-term government cycles** (risks attached to a lack of long-term strategic planning, 14%).

Policy and regulatory standards play a pivotal role in shaping the transition to a circular dairy bioeconomy. However, the landscape is fraught with challenges due to strict and inconsistent interpretations of waste regulations. Additionally, the potential loss of nitrates derogations complicates nutrient management for farmers, affecting both stocking rates and operational costs[15]. However, adopting RENURE standards could mitigate some of these issues by allowing the use of recovered nutrients, thus supporting nutrient circularity and improving water quality[16].

[15] Teagasc report – Nitrates Derogation
[16] Nitrogen Derogation Scheme – gov.ie

Aligning national policies with EU regulations and developing supportive standards and certifications can help create a conducive environment for circular practices. The EU Circular Economy initiative aims to reduce nutrient losses by 50% and fertiliser use by 20% before 2030, highlighting the importance of nutrient recycling in achieving environmental sustainability. The National Biomethane Strategy outlines a comprehensive policy and regulatory framework necessary for developing a robust biomethane industry, which can serve as a model for regulatory support in the dairy sector.

The Corporate Sustainability Reporting Directive (CSRD) introduces stringent requirements for sustainability reporting, impacting the dairy sector by mandating detailed disclosures on a wide range of Environmental, Social and Governance (ESG) factors. This directive applies to all large EU enterprises and listed entities, requiring them to conduct double materiality assessments and provide assurance on reported data. For the dairy sector, this means increased transparency and accountability, driving efforts to reduce environmental impacts and enhance sustainability practices.

Stakeholders have highlighted the need for a mechanism to compare regulatory interpretations across jurisdictions to address inconsistencies. Aligning national policies with EU regulations is complex and requires coherent standards to ensure compatibility and quality of circular bioeconomy (CBE) products. Local authorities often lack the resources and expertise needed to support small-scale projects and emerging technologies, further complicating implementation. Additionally, public funding availability and regulatory barriers hinder the growth of biorefinery technologies.

Implementing technologies and practices that reduce greenhouse gas emissions from dairy farming and processing can further aid regulatory compliance and boost sustainability. Optimising anaerobic digestion (AD) processes and integrating carbon capture and reuse technologies are key strategies in this regard. Emphasising the importance of regulatory and safety validation for recovered products can help avoid market resistance and ensure international competitiveness. A balanced approach between government and industry, with clear roles and responsibilities, is crucial for overcoming these challenges.

Recommendations

Government and Industry Collaboration: Stakeholders emphasised the need for a strong partnership between government and industry to transition to a circular dairy bioeconomy. Stakeholder feedback highlighted the need for alignment of established evidence-based regulatory frameworks from the government, with industry adopting innovative practices. There was also a consensus on the need for better alignment and education on existing policies, indicating a lack of awareness. Regular reviews and joint strategic planning are essential for effective policy integration. Standards and inclusivity

are crucial to mitigate risks and align resources towards common goals. Stakeholders recommend a national effort engaging government bodies, academia, banks and industry to integrate new products and avoid regulatory issues.

While there is consensus on many aspects, opinions diverge on whether leadership should be industry-led or government-led. Some stakeholders advocate for industry-led initiatives through co-ops, emphasising self-help models, while others believe in the necessity of government-led regulation for consistent enforcement.

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*"There is a lack of connectivity between different departments and policy goals. For example, implementation of a biogas programme could be incentivised by an energy feed-in tariff, but these plants could also be central allowing us to address water quality and nutrient objectives - and the lack of a 'policy test' means they could end up being badly sited and in fact work against water and other goals. The scenario in Northern Ireland is a case in point." – **Stakeholder view***

Whole-of-Government Approach: A whole-of-government approach is needed to ensure coherent policy implementation, with multiple departments working together to create a supportive regulatory environment, streamline planning, and address resource challenges. This includes involving the EPA, local authorities, and the community. The survey highlights the need for policy coherence and regulatory flexibility.

Local authorities face challenges due to limited resources and knowledge, requiring a whole-of-government approach. Pre-approved zones for facilities can streamline planning and regulatory processes, making it easier for local authorities to manage applications efficiently.

Sustainable Incentives: Stakeholders highlighted the importance of implementing grants, subsidies, tax credits, feed-in tariffs and low-interest loans to support the adoption of circular bioeconomy practices. Financial incentives are crucial to reduce the upfront costs of adopting new technologies.

Regulation and Safety Validation: Ensuring proper regulation and safety validation for recovered products is necessary to avoid market resistance and maintain international competitiveness. This includes developing standards and certifications for circular bioeconomy products, as well as providing regulatory flexibility or incentives for early adopters of low-carbon technologies. Proper regulation and safety validation help build consumer trust and ensure the quality and safety of bio-based products. Stakeholders emphasised the need for regulatory clarity and support to facilitate the adoption of new technologies.

Planning Reform and Regulatory Alignment: Continuous engagement with regulatory bodies and implementing planning reforms are vital to support market development and

avoid future incompatibilities. This includes strategic positioning of AD plants and associated biorefinery technologies as well as more streamlined planning and permitting processes for them. This includes shared learning among local authorities to reduce the burden on individual planners. Introducing pre-validation processes for emerging technologies can streamline regulatory processes and support the adoption of circular bioeconomy practices. This includes addressing issues around environmental impact assessments (EIA), appropriate assessments (AA), and waste licensing. Stakeholders also highlighted the importance of aligning national policies with EU regulations and developing supportive standards and certifications.

Specific Regulatory Changes Needed: Providing regulatory flexibility or incentives for early adopters of low-carbon technologies and developing standards and certifications for circular bioeconomy products are also necessary. These regulatory changes can help create a supportive environment for the adoption of circular bioeconomy practices and ensure the successful implementation of new technologies.

Educational Initiatives: Educating stakeholders about relevant policies and regulations is crucial for broad awareness and compliance. This includes better information sharing, and support for education and training programmes. Educational initiatives can address resource and knowledge gaps, particularly for local authorities and smaller projects, ensuring successful adoption of circular bioeconomy practices

Financial Strategies and Support

Challenges: **High up-front investment costs, financial uncertainties.**

Key Financial Risk Factors Preventing the Success of a Circular Business Model

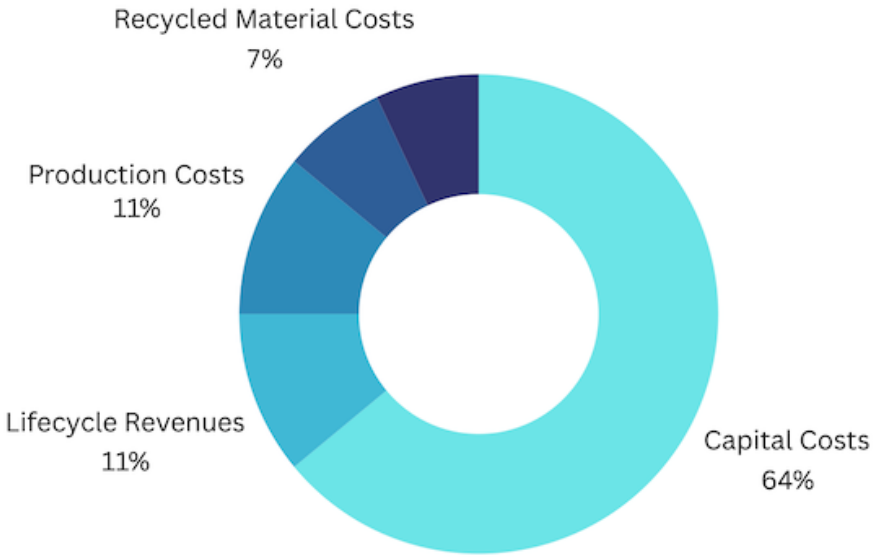

Figure 4: Percentage stakeholder responses to survey question "**What key financial risk factors are preventing a successful Circular Business Model?"** Capital costs (high up-front investment and capital costs for production plants and inventory) were perceived as the highest risk factor (64%). **Lifecycle Revenues** (Lifecycle risk and uncertainty factors related to a possible uncalculated change of revenues due to price volatility of the final product) (11%). **Production Costs**: Increased production costs, including increased costs for energy and maintenance within the production plant (11%). **Recycled Material Costs**: Unforecasted increase of recycled material cost, affecting the economic viability of using recycled materials (7%).

Addressing financial risks is essential for implementing a circular dairy bioeconomy. The financial sector faces obstacles like high upfront investment costs and fluctuating market conditions. However, adopting circular bioeconomy practices can lead to substantial economic benefits, including cost savings, job creation, and long-term financial gains. Successful financial models from the Netherlands' SDE++ programme[17] and Denmark's Green Biorefinery Capital Fund[18] can be adapted to the Irish context to provide financial incentives such as grants, subsidies, tax credits, and low-interest loans.

High initial investments for infrastructure, technology, and production facilities pose major barriers to adopting Circular Business Models (CBMs). These costs can deter investors and businesses, especially without clear financial returns. Revenue uncertainties due to price volatility complicate long-term financial planning, particularly

[17] Netherlands' SDE++ Programmeme
[18] Green Biorefinery Capital Fund

for new circular bioeconomy (CBE) products that lack stable markets. Operational costs, including higher energy and maintenance expenses, impact the financial viability of CBMs. The limited availability and variable costs of recycled materials also pose financial risks. Securing adequate financing is particularly challenging for small and medium-sized enterprises (SMEs) that may lack the financial resources and creditworthiness to attract investment.

Economic Benefits: Adopting circular bioeconomy practices in the dairy sector optimises resource use and reduces waste, enhancing economic viability. On-site anaerobic digestion (AD) can convert dairy processing sludge into biomethane, reducing dependency on natural gas for thermal energy. Exploring carbon capture and storage (CCS) and carbon utilisation (CU) can further address biogenic CO2. Centralised facilities can convert factory and farm residues into biomethane, reducing energy costs and generating revenue. Integrating AD with biorefining processes can extract high-value materials from dairy co-products, creating new revenue streams.

Waste reduction and resource recovery are key principles of the circular bioeconomy. DPTC research has demonstrated multiple avenues for valorisation and nutrient recovery as well as opportunities for waste and energy reduction on processing sites Projects like BiOrbic – Farm Zero C and the national bioeconomy pilot facility at Lisheen show the potential for economic gains by transforming biomass residues into high-value products.

Recovery and reuse of nutrients such as nitrogen and phosphorus can replace mineral fertilisers, reducing input costs and enhancing soil health. Additionally, adopting circular practices can create new job opportunities in the bioeconomy sector, contributing to rural development and economic resilience. For instance, FrieslandCampina in the Netherlands has successfully implemented nutrient recycling and created new jobs through circular practices, demonstrating significant benefits for both the environment and the economy[19].

Recommendations

Government Grants and Subsidies: Direct financial support is essential to reduce the upfront costs of technologies, for both single-output facilities (AD) and advanced biorefineries which aim to fully leverage biomass resources through conversion into an array of biofuels, chemicals, materials and other outputs using biological and thermochemical processes.

The Netherlands' SDE++ programme, which offers incentives for renewable energy projects including biogas from agricultural waste, serves as a useful model. Similarly, the National Biomethane Strategy provides grants and subsidies for biomethane projects.

[19] The Circular Dairy Economy

Stakeholders recommend using structured financial models like public-private partnerships (PPPs), the European Circular Bioeconomy Fund (ECBF) and sustainability-linked bonds. PPPs combine public and private investments to share risks and benefits, while sustainability-linked bonds link financial returns to environmental targets. Standardised designs and modular approaches for biogas plants can also reduce costs and streamline implementation, ensuring scalability and efficiency.

Tax Credits: Offering tax credits for investments in renewable energy systems (e.g., solar panels, biogas systems) and energy-efficient upgrades can lower the financial burden on farmers and processors. This approach has been successfully implemented in the USA through the BioPreferred Program [20], which promotes biobased products with tax incentives and mandatory purchasing requirements for federal agencies.

Low-Interest Loans: Providing access to low-interest loans for capital-intensive projects, such as building biogas plants or upgrading processing facilities, can ease investments in emissions-reducing technologies. Denmark's Green Biorefinery Capital Fund supports green biorefineries through feasibility and capital grants, demonstrating their viability.

Carbon Pricing and Trading: Implementing carbon pricing mechanisms, like carbon taxes or cap-and-trade systems, incentivises reducing greenhouse gas emissions. Revenues can be reinvested in low-carbon agricultural initiatives, creating a market for carbon credits and promoting sustainable practices.

Public-Private Partnerships: These partnerships can leverage private investment in circular bioeconomy projects, providing capital and expertise. For example, Germany's Farm Biogas Association has been instrumental in driving biogas plant delivery by supporting end users with technical expertise and experience.

Funding for Piloting and Demonstration: Supporting the piloting and demonstration of circular bioeconomy processes can help verify technological processes, identify markets, and establish value chains. Austria's effective demonstration and scale-up biorefinery models provide valuable lessons for Ireland.

Support for Value Chain Development: Supporting the development of value chains that integrate circular practices can enhance the economic viability of circular business models. This includes creating comprehensive feedstock databases and developing localised supply chain management strategies.

Tailored Financial Products: Developing tailored financial products and support mechanisms for the circular dairy bioeconomy can address specific financial challenges. This includes creating green bonds and impact investment funds to support the financing of circular bioeconomy projects.

[20] USDA BioPreferred Program

Technological Innovations

Challenges: **Technological risks and efficiency.**

Technological advancements are key to driving the circular dairy bioeconomy forward. Yet the adoption of innovative technologies is often slowed by technical and operational challenges. The complexity and novelty of technologies like biorefining and carbon capture and reuse are significant. These technologies can reduce greenhouse gas emissions and improve nutrient management.

Environmental Benefits

Circular practices offer substantial environmental benefits. They can significantly reduce greenhouse gas emissions, with regenerative dairy farming potentially reducing emissions by 50% and biodiversity loss by 20%, while increasing profitability. AD can reduce methane emissions and integrating it with carbon capture can further enhance carbon efficiency. Circular practices also improve nutrient management by capturing and reclaiming nutrients from dairy waste, reducing water pollution and eutrophication. The EU Circular Economy initiative aims to reduce nutrient losses by 50% and fertiliser use by 20% by 2030. Additionally, circular practices promote biodiversity and optimise land use, creating more resilient agricultural systems.

Biogenic CO2 Management: Anaerobic digestion (AD) produces both biomethane and biogenic CO2. Managing and utilising this CO2 is crucial for maximising AD's environmental benefits. Potential uses include conversion to biomethane, industrial applications (e.g., carbonated beverages), agricultural uses (e.g., enhancing greenhouse plant growth), and carbon capture and storage. Implementing these uses can further reduce the dairy sector's carbon footprint and enhance sustainability.

Emissions from Burning Biogas: Burning biogas, while cleaner than fossil fuels, still produces emissions such as CO_2, NOx, SO_2, CO, and VOCs. However, the overall impact is lower compared to fossil fuels, as biogas combustion results in a net reduction in greenhouse gas emissions due to the lower global warming potential of CO2 compared to methane[21].

Technological and Financial Barriers

Ireland has a rich history in research within the circular bioeconomy space, yet there remains a need to continue developing and optimising a pipeline of innovative processes and solutions. Technologies require significant research and development to optimise efficiency and ensure economic viability. AD processes need to be tailored to specific dairy streams and integrated with biorefining to increase biogas yields. Concerns about the availability and suitability of feedstocks persist, alongside a lack of qualified human

[21] "Biogas – A renewable biofuel"

resources and necessary knowledge to implement these technologies effectively. Financial risks, regulatory barriers, and public funding limitations further complicate the transition to a circular dairy bioeconomy. It is essential to address these challenges while leveraging Ireland's strong research foundation to establish a robust and sustainable circular bioeconomy.

Stakeholders identified challenges with technological advancements, focusing on biorefining, anaerobic digestion (AD), conversion technologies, feedstock enhancement, nutrient circularity, and carbon capture and reuse. Despite the broad and interchangeable nature of these terms, the feedback was insightful. For AD, a well-established technology, there is a noted lack of qualified human resources and knowledge. Conversely, carbon capture and reuse is seen as risky and premature. Additionally, there is a perceived shortage of qualified personnel and expertise in feedstock enhancement. There was a general agreement on the benefits of technological innovations and the need for continued funding in this area.

Key Technology Risk Factors Preventing the Success of a Circular Business Model

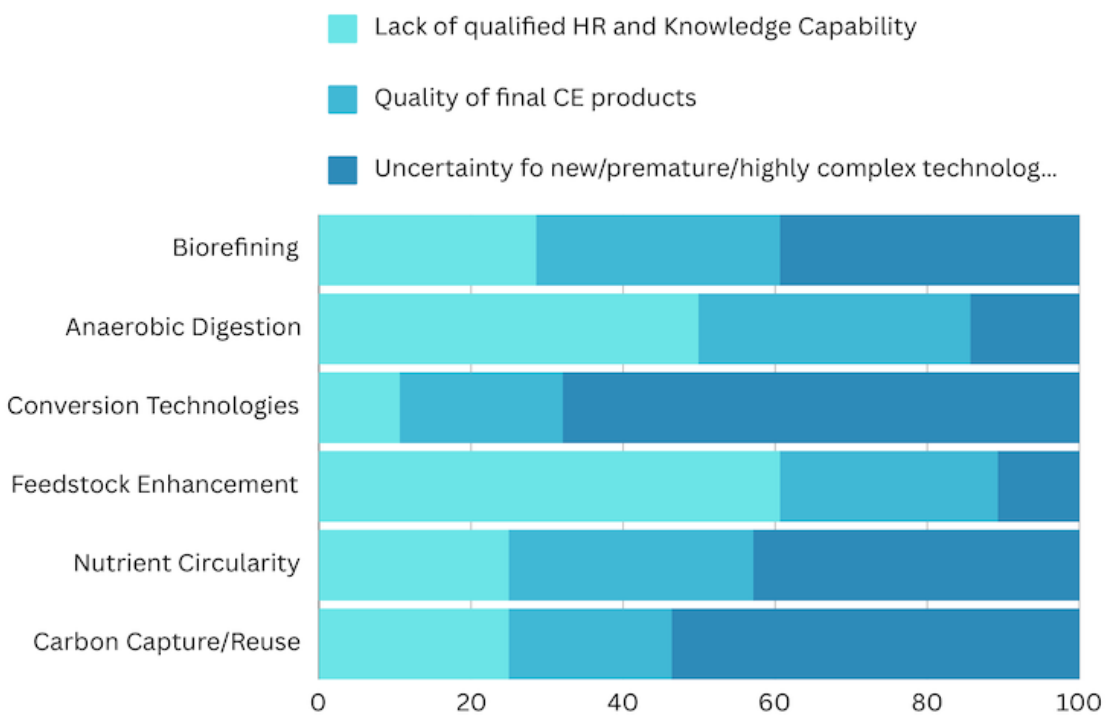

Figure 5: Stakeholder survey responses to the question **"In considering future research, please identify the main risks in relation to technologies that need to be resolved before deployment in a circular business model".**

Recommendations

Nutrient Circularity: Stakeholders recommended a comprehensive assessment and development of new or novel technologies for the reuse of captured nutrients. They emphasised the need for clear and sufficient regulations to reclassify certain wastes as circular nutrients, coupled with improved understanding and education about the regulatory landscape. Ensuring the quality and safety of nutrients recovered from side streams was deemed critical to protect waterways and reduce dependency on chemical fertilisers.

Anaerobic Digestion (AD): For anaerobic digestion, stakeholders highlighted the necessity of considering other feedstocks beyond dairy feedstocks and focusing on process innovation and optimisation. However, wastes and residues should be the primary feedstock. Demonstrating the economic viability of AD technologies at scale through pilot and demonstration sites was seen as crucial. Additionally, increased public funding was considered essential to support the growth of the AD sector.

Conversion Technologies: Stakeholders stressed the importance of addressing the use of resulting nutrients from conversion technologies and ensuring their quality and safety. They recommended integrating conversion technologies into existing systems and scaling them up from lab to industry levels. A holistic approach was needed to avoid promoting one technology over another without considering broader impacts.

Biorefining and Carbon Capture: In the realm of biorefining and carbon capture, stakeholders called for addressing the quality aspects of existing technologies and extracting high-value materials using sustainable and circular processes. Supporting new developments in grass and dairy-related biorefineries was deemed vital. More development was needed at the point of generation for carbon capture to enhance its effectiveness.

Pilot Plants: Pilot projects are essential for demonstrating the viability of these practices and identifying potential issues. For example, pilot and demonstration sites can test financial viability, train technical operatives, and showcase scalable solutions, helping to bridge the gap between research and commercial deployment.

General Technological Barriers: The lack of qualified human resources and knowledge capability must be addressed. Ensuring the quality of final circular bioeconomy products, such as gaps in expected vs. delivered performance, durability, and functionality, is also crucial.

"Apart from technological, quality, and human resources risks, the scalability and financial viability is a critical factor to adopt these technologies. Derisking these factors is important." ***– Stakeholder view***

Collaboration and Knowledge Sharing

Challenges: **Effective collaboration, knowledge sharing.**

Effective collaboration and sharing of resources are fundamental to the circular dairy bioeconomy. However, fostering a cooperative environment remains a significant hurdle. There is a lack of coordinated efforts among stakeholders, including farmers, processors, researchers, and policymakers, which leads to fragmented initiatives and duplicated efforts. Additionally, there is insufficient awareness and understanding of circular bioeconomy opportunities among stakeholders, which hampers the adoption of innovative practices. Trust issues and a lack of long-term relationships further complicate collaboration, as stakeholders may be hesitant to share knowledge and resources. The absence of formal frameworks and platforms for collaboration exacerbates these challenges, making it difficult to establish effective partnerships and knowledge transfer mechanisms.

"Collaborate and share thinking and facilities to develop more circular ways in dairy. ReNure/biofertilisers to be explored appropriately to displace chemical fertilisers and to assist with slurry storage and derogation (allowing economically viable stocking rates to be maintained whilst improving water quality and emissions). Harnessing co-owned structures at scale to unlock value - multi-feedstock and multi-output biorefineries. Stacking ecosystem credits on top of circular bioeconomy initiatives." ***– Stakeholder view***

Recommendations

Encourage cross-sectoral collaboration and partnerships: Foster partnerships between farmers, processors, researchers, and policymakers to create a unified approach towards the circular bioeconomy.

Promote joint thinking across government and industry: Regular reviews incorporating industry input and joint thinking across government agencies and industry are essential to ensure smooth integration of new products and practices.

Regional Hubs and Advisors: Establish regional hubs and appoint circular bioeconomy advisors to connect stakeholders, share knowledge, and support the development of local circular bioeconomy initiatives. However, while the number of initiatives and forums is well-intended and making progress, the multitude of separate initiatives can sometimes slow overall progress.

Engage stakeholders at all levels: Build trust and foster long-term relationships by involving stakeholders in decision-making processes and collaborative projects.

Enhance community involvement: Include the entire community in the process to improve perceptions and ensure the success of bio-based products. Engage local communities in the development and operation of circular bioeconomy projects to build local support and ensure shared benefits.

Implement education and training programmes: Increase awareness and understanding of circular bioeconomy opportunities through targeted education and training initiatives.

Leverage existing networks: Utilise existing networks and platforms to facilitate knowledge sharing and collaboration, ensuring that all stakeholders are engaged and informed.

International Best Practices

Challenges: **Adapting international best practices.**

Adapting international best practices to the Irish context presents several challenges. Different countries have varying regulatory frameworks, market conditions, and technological advancements, making direct application difficult. The scale and scope of dairy operations also differ significantly, affecting the feasibility and effectiveness of certain practices. For instance, large-scale biogas plants may be viable in countries with extensive dairy operations but less effective in regions with smaller, fragmented farms. Additionally, the availability of financial resources and government support varies, impacting the ability to implement and sustain circular bioeconomy initiatives. Understanding and navigating these differences is crucial for successfully adapting international best practices to enhance the sustainability and economic resilience of the Irish dairy sector.

Comparative Analysis of International Best Practices:

Denmark: Denmark leads in the bioeconomy, particularly in the agri-food sector. The Green Biorefinery Capital Fund supports biorefineries through grants. Denmark's Biomasspott.dk platform connects farmers, industries, and energy producers to trade agricultural residues and organic waste, improving resource efficiency and reducing emissions. Their support for biomethane production offers valuable lessons for Ireland.

The Netherlands: The Netherlands excels in circular bioeconomy practices, especially in renewable energy. The SDE++ programme[22] provides financial incentives for renewable energy projects, including biogas production from agricultural waste. This financial support makes investments in anaerobic digestion viable. The Dutch dairy sector is innovative in circular practices, optimising grazing and high-tech farming to close nutrient, water, carbon, and waste cycles.

Germany and Austria: Germany's Farm Biogas Association[23] supports biogas plant delivery with technical expertise, overcoming regulatory challenges. Austria and Germany have developed effective biorefinery models, integrating technical support with policy and financial incentives, offering a comprehensive model for Ireland.

United States: The BioPreferred Program by the USDA[24] promotes biobased products through mandatory purchasing requirements for federal agencies and a voluntary labelling initiative. This programme reduces reliance on petroleum, increases renewable agricultural resources use, and reduces environmental impacts. It provides a framework Ireland could adapt.

[22] SDE++ Programme, Netherlands
[23] Biogas.org
[24] BioPreferred Program

New Zealand: New Zealand's pasture-based system offers insights for Ireland. Their focus on sustainable farming and biorefinery models at the farm level provides practical examples. Emphasising local adaptations and tailored solutions for specific contexts is key.

Recommendations

Draw Insights from Successful Initiatives: Adapt effective strategies from Denmark, the Netherlands, the USA, Germany, Austria, and New Zealand in areas like biogas production, nutrient recycling, and biorefinery development. For example, Denmark's Green Biorefinery Capital Fund and the Netherlands' SDE++ programme offer valuable financial support models.

Develop Comprehensive Policy Frameworks: Create policies that support circular bioeconomy practices, including regulatory flexibility, and supportive standards. Align these frameworks with successful international models like the EU Circular Economy initiative.

Promote Financial Incentives and Support Mechanisms: Implement grants, subsidies, tax credits, and low-interest loans to reduce the costs of adopting new technologies. Public-private partnerships and innovative financing models from Germany and the Netherlands can provide the necessary capital and expertise. For example, a Feed-In Tariff (FIT) was suggested as a potential support for the nascent AD economy[25]. This is a mechanism commonly deployed across the globe, particularly in the US and Japan.

Foster Cross-Sectoral Collaboration: Encourage sectors to share knowledge and best practices through formal partnerships with leading countries in the circular bioeconomy. Organise workshops, conferences, and study tours to learn from international experiences.

Support Pilot Projects and Demonstration Sites: Invest in pilot projects and demonstration sites to test and refine circular practices. Experiences from Austria and Germany, which have successfully implemented demonstration projects, can guide Ireland.

Enhance Resource Allocation and Technical Support: Allocate more resources and expertise to support circular practices. Provide technical support and training to farmers and processors, similar to Germany's Farm Biogas Association. Develop local technical support networks to overcome implementation challenges.

[25] Feed-In Tariff (FIT): Explanation, History, and Uses

Summary

Market Development and Consumer Perception: The primary market risk factors identified include the uncertainty of market size for biobased products and consumer perception issues. Stakeholders emphasised the need for robust market development supported by government policies and regulations. Enhancing consumer perception through education and independent validation, along with financial incentives such as grants and subsidies, are crucial steps to mitigate these risks.

Supply Chain Stability: Ensuring a consistent and reliable supply of feedstocks is a major concern. Seasonal variations pose significant challenges. Stakeholders recommended diversifying feedstocks, involving local communities and cooperatives, and developing comprehensive databases to manage feedstock availability and characteristics effectively.

Policy and Regulatory Support: Regulatory barriers and policy coherence are critical challenges. The need for harmonised waste regulations and supportive standards and certifications was highlighted. A whole-of-government approach involving various government bodies, academia, and industry is necessary to create a supportive regulatory environment and streamline planning processes.

Financial Strategies and Support: High upfront investment costs and financial uncertainties are significant barriers to adopting circular business models. Stakeholders recommended leveraging structured financial models such as public-private partnerships and sustainability-linked bonds. Providing direct financial support through grants, subsidies, tax credits, and low-interest loans is essential to reduce the financial burden on businesses.

Technological Innovations: The complexity and novelty of technologies like anaerobic digestion, biorefining, and carbon capture and reuse present significant challenges. Stakeholders emphasised the need for continued research and development, pilot projects, and demonstration sites to optimise these technologies and ensure their economic viability.

Centralised Bio-Refining: Promoting centralised bio-refining can enhance efficiency and economies of scale. Collaboration with the biomethane industrial partnership and other stakeholders is essential to support research and development in this area. Centralised bio-refining can also facilitate the valorisation of various feedstocks, optimising resource use and reducing environmental impacts.

Collaboration and Knowledge Sharing: Effective collaboration and knowledge sharing are critical for the successful transition to a circular bioeconomy. Stakeholders recommended fostering partnerships between farmers, processors, researchers, and

policymakers, implementing education and training programmes, and leveraging existing networks to facilitate knowledge sharing and collaboration.

Adapting International Best Practices: Adapting international best practices to the Irish context requires understanding and navigating differences in regulatory frameworks, market conditions, and technological advancements. Stakeholders recommended drawing insights from successful initiatives in countries like Denmark, the Netherlands, Germany, Austria, and New Zealand, and tailoring these best practices to fit the unique Irish context.

Summary of key recommendations:

For nutrient circularity, prioritising nutrient recycling to reduce environmental impact and extracting nutrients before effluent treatment is crucial. In anaerobic digestion, optimising processes to boost biogas yields and implementing high-rate AD for select dairy streams can significantly displace on-site natural gas use. Biorefining should focus on converting dairy co-products into valuable products. For carbon capture, capturing and reusing emissions could be a potential means to meet sustainability goals. Finally, securing additional funding and developing infrastructure to support research and demonstration projects is vital for advancing sustainable technologies.

Conclusion and Recommendations

The transition to a circular bioeconomy presents both challenges and opportunities for the Irish dairy sector. Key points discussed in this stakeholder analysis include the sector's significant contribution to national greenhouse gas emissions and its impact on waterways, the high up-front investment costs required for infrastructure and technology, and the need for consistent regulatory frameworks and market development. Stakeholders have identified the importance of innovative practices such as nutrient recycling, anaerobic digestion, and biorefining to transform dairy co-products into valuable resources, promoting both economic viability and environmental sustainability.

Final Recommendations: For the government, it is crucial to provide financial incentives such as grants, subsidies, tax credits, and low-interest loans to reduce high up-front investment costs. Alignment with established regulatory frameworks, including emissions reduction targets and flexible regulations for early adopters, is essential. The industry should focus on promoting cooperative models, improving consumer perception through independent validation and education, and supporting comprehensive bioeconomy strategies. Farmers are encouraged to engage in cross-sectoral collaboration and knowledge sharing through formal frameworks and educational programmes. Supporting ongoing research and development, optimising technologies like high-rate reactors and feedstock enhancement, and conducting pilot projects and demonstration sites are necessary steps.

Call to Action: According to the '*Circular Bioeconomy Outlook Study 2030-2050 in Support of Climate Action, Sustainable Food and Biobased Systems*[26],' a sustainable circular bioeconomy is essential for Ireland's transition to a climate-neutral economy while maintaining its competitiveness. This approach is vital for the Irish dairy sector, enabling decarbonisation, protecting waterways, enhancing biodiversity, and boosting economic resilience. Achieving these goals requires a collective effort from all stakeholders to implement and continuously improve the recommended strategies.

[26] Circular Bioeconomy Outlook Study 2030 - 2050

APPENDIX 1: Further work needed

Market Design and Supply

Develop Detailed Implementation Strategies: Comprehensive plans for cooperative models and market engagement are needed. These strategies should outline specific steps for integrating cooperative models, addressing practical challenges related to co-ownership and risk-sharing, and effective market development.

Conduct Consumer Education Campaigns: Improving consumer perception of circular bioeconomy products is crucial. This can be achieved through targeted education campaigns and independent validation initiatives that highlight the quality and benefits of these products.

Create Comprehensive Databases for Feedstocks: Establishing detailed and comprehensive databases for feedstocks is essential for managing supply chain stability. These databases should include information on the availability, quality, and seasonal variations of feedstocks, ensuring a consistent and reliable supply of raw materials.

Develop Localised Strategies for Supply Chain Management: Tailored strategies for different regions can help manage supply chain risks more effectively. These should focus on utilising underused pasture lands, involving farmers in the ownership and operation of biogas plants, and implementing strategic management of standards.

Environmental and Social Benefits: Highlighting the environmental and social benefits more explicitly, such as reduced greenhouse gas emissions, improved soil health, and community engagement.

Policy and Regulatory Support

Clarify Roles and Responsibilities: Define the roles of different stakeholders (government, industry, farmers, community) in the transition to a circular dairy bioeconomy.

Develop Specific Policy Frameworks: Create detailed policy frameworks and regulatory guidelines to support circular practices, including pre-validation processes for emerging technologies.

Conduct Pilot Projects: Implement pilot projects to test and refine regulatory approaches, ensuring they are practical and effective.

Promote Cross-Sectoral Collaboration: Encourage collaboration between different sectors to share knowledge and best practices, fostering innovation and efficiency in the circular dairy bioeconomy.

Metrics and Evaluation: Establish clear metrics and evaluation criteria to measure the success of circular bioeconomy initiatives in the dairy sector.

Financial Strategies and Support

Create Tailored Financial Products and Support Mechanisms: Develop financial products specifically designed for the circular dairy bioeconomy, such as green bonds, impact investment funds, and sustainability-linked loans. These products can provide the necessary capital while aligning with environmental goals.

Conduct Comprehensive Economic Impact Analyses: Perform detailed economic impact analyses to quantify the financial benefits of circular practices. This includes assessing potential cost savings, job creation, and long-term financial benefits to demonstrate the economic viability of circular bioeconomy initiatives.

Develop Risk Management Strategies: Create comprehensive risk management strategies to address financial uncertainties. This involves identifying potential risks, such as market volatility and regulatory changes, and developing mitigation plans to ensure financial stability.

Enhance Resource Allocation: Allocate more resources and expertise to local authorities to support small-scale projects and streamline development processes. This includes providing additional funding and training to help local authorities manage and support circular bioeconomy initiatives more effectively.

Technological Innovations

Anaerobic Digestion (AD): AD is an established technology, however further innovation is required on feedstock enhancement, process innovation and optimisation, considering diverse feedstocks and demonstrating economic viability through pilot sites. More research is needed on specific technological innovations and their potential impact on the circular dairy bioeconomy. For instance, detailed case studies or examples of successful anaerobic digestion projects.

Nutrient Circularity: Develop technologies for nutrient reuse, ensure regulatory clarity, and maintain nutrient quality and safety.

Biorefining and Carbon Capture: Enhance existing technologies, support new developments, and improve carbon capture at the point of generation.

Pilot Plants: Establish pilot projects to test financial viability, train personnel, and showcase scalable solutions.

Address Technological Barriers: Increase qualified human resources, improve knowledge capability, and ensure the quality of circular bioeconomy products.

Collaboration and Knowledge Sharing

Establish formal collaboration frameworks and stakeholder forums: Create structured platforms for regular interaction and collaboration among stakeholders.

Develop comprehensive knowledge transfer programmes and educational initiatives: Design and implement programmes that facilitate the sharing of best practices, research findings, and technological advancements.

Conduct stakeholder engagement activities: Organise workshops, seminars, and other engagement activities to build trust, encourage collaboration, and ensure all voices are heard in the transition to a circular bioeconomy.

Enhance industry-academia collaboration: Increase the involvement of industry stakeholders in research initiatives to bridge the gap between academic research and practical application.

Support local self-help initiatives: Encourage cooperative models and local self-help initiatives to achieve circular bioeconomy goals, reducing dependency on European policies and subsidies.

International Best Practices

Conduct Comparative Studies: Identify the most relevant international practices and tailor them to the Irish context by analysing regulatory frameworks, financial instruments, and technological advancements.

Develop Adaptation Strategies: Create strategies to adapt international best practices to local conditions, leveraging international insights to address the unique challenges and opportunities in the Irish dairy sector.

Promote Knowledge Exchange: Foster collaboration with international partners to share best practices, technical expertise, and innovative solutions through formal partnerships.

Implement Pilot Projects: Support pilot projects to test and refine adapted practices, demonstrating the viability of new technologies and approaches in the Irish context.

Enhance Policy and Regulatory Support: Align policy and regulatory frameworks with international best practices, developing supportive policies that incentivise circular practices and facilitate the adoption of innovative solutions.